

Heatsinks

by G. C. OXLEY, G8MW*

THE rating of all electrical equipment is determined by its working temperature. If the apparatus gets too hot then insulation may catch fire or melt, conductors expand and semiconductor junctions can be destroyed. In the specific case of semiconductors the device is usually kept cool by using a heatsink. Keeping the temperature of semiconductor devices within the specified limits is also important because their operating characteristics alter with changes in temperature. This is particularly important with zener diodes, Class B amplifiers and temperature-limited voltage regulators.

The heatsink loses heat to its surroundings by convection, radiation and conduction. Mounting the heatsink vertically, so as to give as good a flow of air as possible, will help the convection of heat. The larger the volume of metal, the more heat it will absorb; but the most important factor is the surface area of the heatsink. This area can be increased by adding "radiating" fins. When natural convection takes place the rate of heat loss in a constant-temperature enclosure is proportional to $\theta^{1.2}$, where θ is the temperature excess over the surroundings. Loss of heat by radiation can be enhanced by painting the heatsink matt black or by anodizing.

A rough comparison of the ability of some metals to conduct heat is given in Table 1.

Table 1. Heat conductivity of some metals

Silver	Ag	100	Brass	25
Copper	Cu	80	Iron	15
Aluminium	Al	40	Lead	8
Zinc	Zn	30		

When cost and ease of working are considered, aluminium comes out best; but copper, zinc and brass can all be used, and these metals are easily soldered (plumbers' solder). The working temperature of the device and the power that it needs to dissipate must be known before a heatsink can be designed. Considerations of cost, weight and space will require the size of the heatsink to be kept to a minimum.

The opposition to a body losing heat is called its thermal resistance. This is usually denoted by θ and is expressed in $^{\circ}\text{C/W}$ [1].

Rectifier diodes, large zener diodes and transistors dealing with more than about 0.5W are often provided with heatsinks in order to achieve a higher power output. A rule-of-thumb value for the working temperature of silicon junctions is approximately 150 $^{\circ}\text{C}$, and for germanium junctions 75 $^{\circ}\text{C}$.

The rating of rectifier diodes is often related to the temperature of the stud (bolt) T_S . Fig 1 shows that the output current of this diode must be halved if the temperature T_S rises from 50 $^{\circ}\text{C}$ to 100 $^{\circ}\text{C}$.

Examples using diodes and voltage regulators

A rectifier diode has a forward voltage drop of 1V when delivering a current of 5A. The stud temperature must not exceed 80 $^{\circ}\text{C}$ when the rectifier is dissipating 5W. Let the air

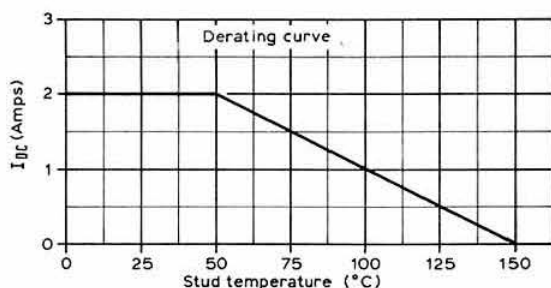


Fig 1. Diode rating related to stud temperature

(ambient) temperature inside the rectifier compartment be $T_A = 50^{\circ}$, then

$$\frac{T_S - T_A}{P_D} = \frac{80 - 50}{5} = 6^{\circ}\text{C/W}$$

From the curves, Fig 2, an aluminium heatsink would need to be approximately 260cm² in area of one side. The dimensions of a square heatsink would be $\sqrt{(260/2)} \times \sqrt{(260/2)} = \sqrt{130} \times \sqrt{130}$, and a 12cm by 12cm piece of 1.5mm aluminium sheet would be suitable. Painting the sheet with matt black paint would give an added safety margin of about 20 per cent.

Manufacturers often draw heatsink characteristics on logarithmic graph paper, the result being nearly a straight line. Fig 2(a) shows the rapid increase in area needed as the thermal resistance falls below 5 $^{\circ}\text{C/W}$ or so, while Fig 2(b) shows that the area and material become of less importance above 30 $^{\circ}\text{C/W}$.

Fig 3 shows a diode rectifier mounted on a heatsink. Heat must be conducted away from the junction to the case, and this path has a thermal resistance of θ_{J-C} $^{\circ}\text{C/W}$. From the case to the heatsink the resistance is θ_{C-HS} , and from the heatsink to the surroundings θ_{HS-A} . Adding these together:

$$\theta_{J-A} = \theta_{J-C} + \theta_{C-HS} + \theta_{HS-A}$$

The same conditions apply also to transistors and voltage regulators. Compact and cheap voltage regulators are now available, and best results are obtained by using adequate heatsinks.

For a regulator required to supply 3A at 12V the input voltage will be about 14.5V, but to allow for mains variations, transformer and rectifier tolerances, this input may reach 17V. At maximum output the regulator must dissipate $5 \times 3 = 15\text{W}$. If $T_A = 50^{\circ}\text{C}$ and $T_J = 150^{\circ}\text{C}$:

$$\theta_{J-A} = \frac{150 - 50}{15} = 6.7^{\circ}\text{C/W}$$

$$\theta_{J-C} + \theta_{C-HS} + \theta_{HS-A} = 6.7^{\circ}\text{C/W}$$

$$\theta_{HS-A} = 6.7 - \theta_{J-C} - \theta_{C-HS}^{\circ}\text{C/W}$$

The manufacturer of one such regulator gives the value of θ_{J-C} as 3 $^{\circ}\text{C/W}$. A figure for the value of θ_{C-HS} can range from 0.1 $^{\circ}\text{C/W}$ to 0.5 $^{\circ}\text{C/W}$, depending on whether an insulating washer and bushes are used and upon good surface contact, aided by a thermal compound such as silicone grease. If a figure of 0.3 $^{\circ}\text{C/W}$ is chosen:

$$\theta_{HS-A} = 6.7 - 3 - 0.3 = 3.4^{\circ}\text{C/W}$$

From Fig 2, an aluminium plate approximately 17cm square would be suitable as a heatsink.

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Fig 2. (a) Thermal resistance related to surface area. (b) Graph showing reduced importance of area and material at higher thermal resistance

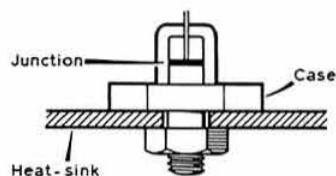
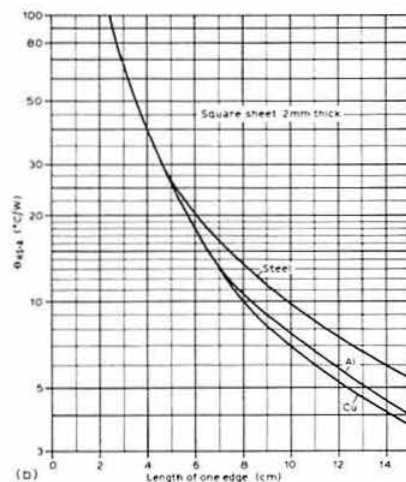
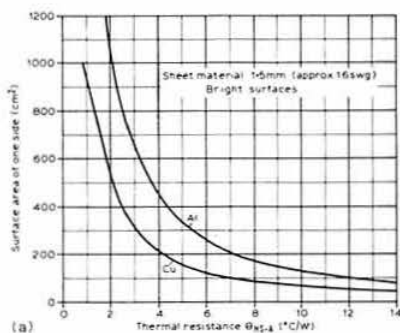


Fig 3. Diode rectifier mounted on heatsink

Examples using transistors

BFY50. If the temperature of the case can be kept below 100°C then the power dissipated can be 2.86W . θ_{JA} is quoted as 220°C/W .

$$P_D = \frac{T_J - T_A}{\theta_{JA}} = \frac{200 - 25}{220} = \frac{175}{220} = 0.8\text{W}$$

This is the power which a BFY50 will handle in surroundings having a temperature not exceeding 25°C . The derating curves are given in Fig 4.

Let the desired output be 2W

$$\theta_{HS-A} = \frac{200 - 50}{2} - \theta_{J-C} - \theta_{C-HS} = 75 - 35 - 1 = 39^{\circ}\text{C/W}$$

Because this transistor has a TO-5 can a rather higher figure is chosen for θ_{C-HS} .

Note, case is connected to collector.

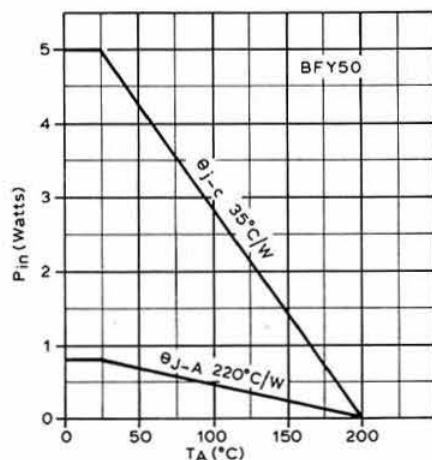


Fig 4. Derating curves of a BFY50

BLY85. VHF transistor.
Let $P_D = 5\text{W}$

$$\theta_{JA} = \frac{150 - 50}{5} = 20^{\circ}\text{C/W}$$

$$\begin{aligned} \theta_{HS-A} &= 20 - \theta_{J-C} - \theta_{C-HS} \\ &= 20 - 12.5 - 0.5 = 7^{\circ}\text{C/W} \end{aligned}$$

The data sheet gives $R_{th(J-mb)}$ instead of θ_{J-C} . The term 'mounting base' is used instead of 'case'. The torque applied to the nut on the fixing stud is quoted as between 7.5kg/cm and 8.5kg/cm . Tight, but not too tight.

TIP42. This low frequency power output transistor will dissipate 2W continuously if the free air temperature does not exceed 25°C . Let the required output be 10W

$$\theta_{HS-A} = \frac{150 - 50}{10} - \theta_{J-C} - \theta_{C-HS} = 10 - 1.92 - 0.5 = 7.5^{\circ}\text{C/W}$$

Practical considerations

Heatsinks can be bought from retailers; one heatsink, made by Marston Excelsior Ltd, is shown in cross-section in Fig 5. With the fins vertical in free air, a 100mm length has a thermal resistance of 2.1°C/W .

For a length of 100mm the performance is shown in the graphs of Fig 6.

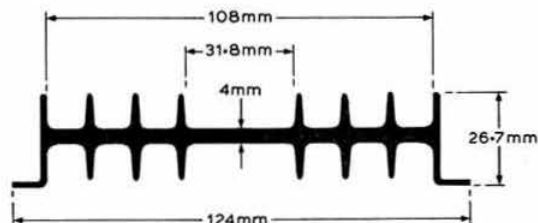


Fig 5. Cross-section of a Marston heatsink

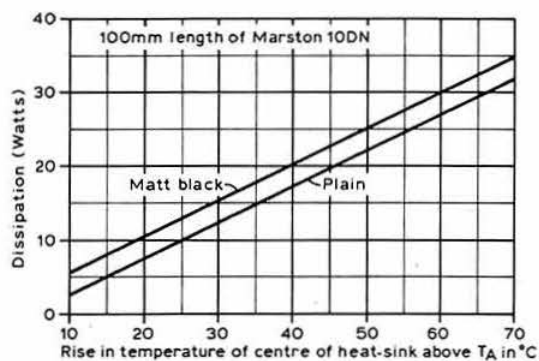


Fig 6. Performance graph of Marston 10DN heatsink

For a dissipation of 25W with $T_{HS} - T_A = 50^\circ\text{C}$,

$$\theta_{HS-A} = \frac{50}{25} = 2^\circ\text{C/W.}$$

Care should be taken to make sure that the surface of the heatsink is as smooth and flat as possible. Apply the correct fixing pressure to the securing nuts and bolts, and use a thermal conducting grease. When no insulating washers are needed use bolts or screws which fill the fixing holes and use flat washers under the nuts. If the heatsink must be mounted horizontally its size should be increased by a factor of 1.3.

Home-made heatsinks

Details are given in the handbooks. Copper-clad board can be used; if clad on both sides, the copper should be bonded.

Transistors with TO-5 cans are best sunk into an 8.5mm diameter hole drilled into the sink [2].

Aluminium or brass vanes from old tuning capacitors, as well as discarded aluminium sole-plates of smoothing irons, can be adapted.

Manufactured heatsinks

Manufacturers of heatsinks and radiators include Redpoint Ltd, Lynton Road, Cheney Manor, Swindon, Wilts SN2 2QN; Staver Thermal Products (UK) Ltd, Heron Trading Estate, Bruce Grove, Wickford, Essex SS11 8BS; and Fischer-Electronik, c/o DAU (UK) Ltd, 42a Main Road, Barnham, Bognor Regis, Sussex PO22 0ES.

Well-illustrated broadsheets and catalogues are available from these and other manufacturers.

Acknowledgements

The writer wishes to thank Marston Excelsior Ltd, STC, Texas Instruments, Lambda Electronics and Mullard for technical information.

References

- [1] "How to solve transistor heatsink problems", Courtney Hall, WASSNZ. *Ham Radio* January 1974, p46.
- [2] "Low-power transistor transmitter", G. R. Kennedy. *Wireless World* October 1968, p350. □

EQUIPMENT REVIEW

Quartz 16 144MHz fm transceiver

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Introduction

To many mobile operators the appeal of 144MHz fm is the simplicity of the equipment. It is not necessary to tune the receiver, to net the transmitter or adjust any other controls while, at the same time, driving a vehicle. But many of the fm black boxes now on the market have become very sophisticated with their synthesizers, led readout of frequency, scanners, simplex/duplex switching etc, and have lost some of that ease of use.

The Quartz 16 represents a straightforward 23-channel, crystal-controlled, 144MHz fm transceiver which has a performance which is just as likely to make and maintain contacts as

its "all singing, all dancing" brothers. The advantage of synthesized equipment is the large number of channels that can be called up, but often (particularly outside the London area) only a handful of channels are used, eg a couple of local repeaters and half a dozen simplex channels. Having more frequencies than required only makes the unit more difficult to use without taking one's eyes off the road.

The unit used in the review was kindly loaned by Waters & Stanton Electronics, who can supply the Quartz 16 with seven channels fitted for £149.75, and an additional three channels for £7.50, both including VAT and delivery.

Description

The transceiver is housed in a black steel case with diecast alloy front and back panels. The main circuitry is built on two glass-fibre printed circuit boards accessible by removing the top and bottom covers. The unit is supplied with a well-designed and mobile mounting bracket which has two quick-release catches, making it very easy to put in or remove from a car. This means that the same equipment could be used for home station and mobile operation, or that the transceiver can be safely locked in the boot when the car is left unattended. The main control is a centrally mounted 23-way channel selector switch which also has a position for an external vfo. There is an additional switch for selecting two priority channels, which could, for instance, be the mobile calling channel (145.500MHz) and a club frequency. The power is turned on by pushing the volume control knob. Pulling the squelch knob switches on the automatic 1,750Hz toneburst oscillator for repeater access. High or low power can be selected by a small lever switch.

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